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Effect of fuel content on luminescence and antibacterial properties of zinc oxide nanocrystalline powders synthesized by the combustion method†

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Nanoscale ZnO powders were synthesized via the combustion method using zinc nitrate hexahydrate as the oxidizer (oxidant) material and urea, and glycine or citric acid monohydrate as fuels. The effect of the relative fuel to oxidant ratio on the characteristics of ZnO particles produced with urea as the fuel was also investigated. X-ray diffraction analysis revealed that the ZnO nanocrystalline particles were successfully synthesized by combustion and the crystallite size was different depending on the fuel. The surface morphology showed a dramatic change as the fuel changed in the synthesis process. The chemical states of the synthesized ZnO powders were investigated using X-ray photoelectron spectroscopy, which allowed an assessment of the Zn and O related defect concentrations. The optical bandgap varied from 3.12 to 3.14 eV for different fuels and it decreased to 3.10 eV in the fuel rich case for urea. The maximum defect level photoluminescence emission was observed for the ZnO powder synthesized using urea as the fuel, for the stoichiometric fuel mix. All products exhibited similar antibacterial effects, however they had a greater effect on Staphylococcus aureus compared to Escherichia coli.

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1. Introduction

Nanoscale ZnO powder has attracted great attention due to its excellent physical and chemical properties. It is widely used in nanoscale devices such as nanogenerators,[1] ultraviolet photodetectors,[2] gas sensors,[3] solar cells,[4] field emission displays,[5] electrical and optical devices,[6] photocatalysis,[7] radiation[8] and environmental applications.[9] These nanomaterials have novel electronic, structural and thermal properties which have potential interest in basic and applied research. ZnO is a wide band gap (E_g = 3.37 eV) semiconductor with a large free exciton binding energy (60 meV).[10] Semiconductor nanocrystals or nanoparticles may have superior optical and antibacterial properties than bulk crystals due to quantum confinement effects and the large surface to volume ratio. The synthesis and properties of ZnO nanostructures such as nanowires,[11] nanotubes,[12] nanorods[13] and nanoparticles[14] have been reported. The nanoparticles have great significance as these dimensional confined systems bridge the gap between bulk materials and molecular compounds. A variety of techniques have been employed for the synthesis of ZnO nanoparticles such as sol–gel synthesis,[15] the hydrothermal method,[16] the solution combustion method[17] and solid state reactions.[18] Among these, the combustion technique is noteworthy as a fast method to synthesize nanocrystalline materials in a synthesized form with large surface area without the further need of heat treatment. Nanocrystalline oxides are produced through the redox reaction between an oxidizer containing the metal precursor and an organic fuel at a moderately low initiation temperature of around 350–600 °C within a few minutes.[19] The main advantage of this method is that the high temperature of the exothermic reaction assures high purity and well crystallized powder. In combustion synthesis, the type of fuel and the fuel to oxidizer ratio (F/O) play critical roles in influencing the nature of combustion reaction and the flame temperature. Patil and Sivananda[20] synthesized ZnO powder by the combustion method using different fuels in solution (citric acid, dextrose, glycine, malic dihydrazide, malic acid, and urea) and investigated structural, optical and textural properties. They observed that crystallite size and bandgap of ZnO was influenced by different fuels. Different modifications made to conventional combustion approaches for preparation of nanomaterials are critically analyzed by Arora et al.[21] They described that the combustion process involves a self-sustained reaction in a homogeneous solution of different oxidizers (metal nitrates) and fuels (urea, glycine, hydrazides). It is concluded that fuels in the combustion synthesis process play an important role to get nanosize oxide

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